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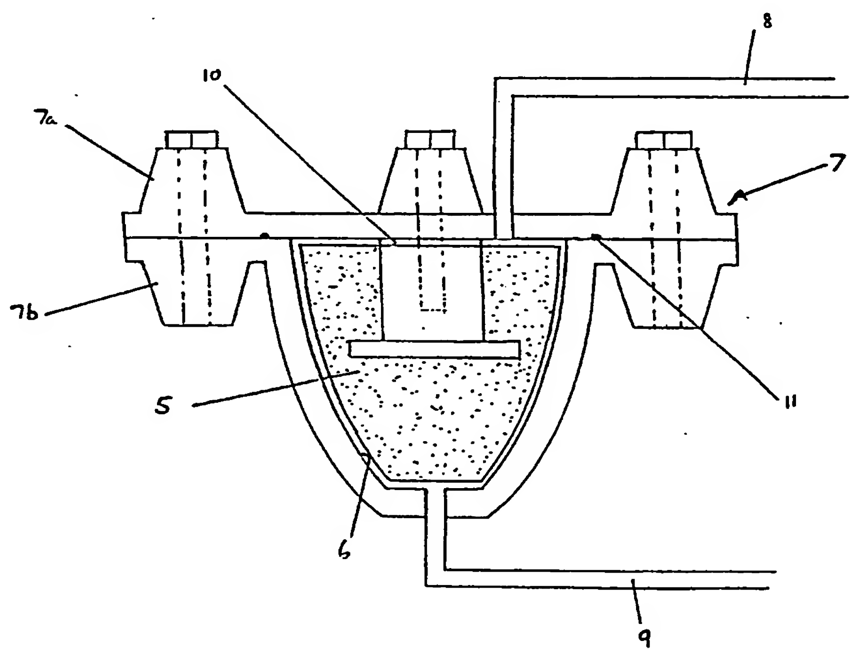

(57) Abstract

A plug for vacuum forming of thermoplastics comprises a two-part metal insert (3, 4) screwed together and bonded to two pieces of syntactic material (1, 2). The syntactic material is machined to the desired shape (5) coated with heat resisting material and utilised in a vacuum tool (7). The plug is less liable to breakage than hitherto. A roller comprising a core of steel (23) carrying syntactic material (22) and an elastomeric coating having superior wear resistance is also disclosed.

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COATING SYNTACTIC ARTICLES

This invention relates to a method of coating syntactic articles and to coated syntactic articles. The invention is particularly concerned with the coating of syntactic plugs and rollers for use in vacuum forming.

Vacuum forming is a shaping process applied to a heated sheet of thermoplastics material by clamping the heated sheet in a holder, and then applying a vacuum (suction) when the sheet is in a pliable or "rubbery" state. Vacuum forming is a widely used process, being used extensively for making articles such as disposable plastic cups, trays and tubs. Polyethylene, polypropylene, PVC, ABS, polystyrene and Saran are all suitable plastics materials for vacuum forming.

Plug-assist vacuum forming is an improved process which results in better control of wall thickness and increased processing speed. It also leads to a reduction in the amount of plastics material used. In this process, a heated sheet of plastics material is clamped over a mould, and a plug forces the sheet down into the mould cavity. As the plug engages the sheet, the air beneath the sheet is compressed, causing the sheet to billow up around the plug. This billowing action prevents the sheet from touching the cavity lip as the sheet is stretched into the cavity. The plug stops near the base of the mould, the mould is evacuated, and the sheet is tranferred from the plug to the mould by suction pressure. Once the

article is formed, the plug is removed.

Traditionally, the plugs for use in this process are made of resin-impregnated felt. Unfortunately, plugs of this type cannot withstand the higher temperatures to which some new plastic materials need to be raised for vacuum forming. Moreover, they cannot cope with modern high-speed machines, which typically have a cycle time of about two seconds. Plugs have also been made of Delrin. Unfortunately, at high temperatures, this material breaks down and gives off the toxic gas formaldahyde. Thus, not only are Delrin plugs unsatisfactory for use at high temperatures, but they also give rise to a health hazard. Recently, therefore, plugs have been made of syntactic foam material. A syntactic foam is a composite material in which light-weight particles are bonded together in a matrix of high-strength resin, usually either epoxy or polyester. In order to make plugs of syntactic foam material, the light-weight particles may be microspheres, that is to say small hollow glass bubbles. A syntactic foam material has a low density and very good heat-insulating properties. It is, therefore, inherently suitable for forming plugs for a plug-assist vacuum forming process, as such plugs need to be good heat insulators, otherwise heat flows into the plugs from the heated plastic sheets, which detrimentally affects the vacuum forming operation. Unfortunately, plugs made of syntactic material tend to be too brittle at the high temperatures and speeds required for modern machines and

new plastics materials. Syntactic plugs are also subject to excessive wear, tend to breakdown under high temperatures, are subject to excessive frictional forces, and are liable to shatter under fast punching conditions, particularly when first starting up if adequate pre-melt time is not allowed. Moreover, a syntactic plug can break up when retracted if, as sometimes happens, the punched sheet closes slightly over the plug.

One aim of the invention is, therefore, to provide a syntactic plug which can be used with modern high-speed vacuum forming machines and new plastics materials.

Another problem has arisen with modern high-speed plug-assist vacuum forming machines when used with the new plastics materials which need to be heated to about 170°C to 180°C, namely that the rollers used to transport the sheets of plastics material to the machine are inadequate. Such rollers need to be good heat insulators, whilst having a sufficiently high coefficient of resistance to ensure that the sheets are fed to the machine at the required high rate. These rollers also need to have a high degree of wear resistance. Up to now, syntactic rollers have proved to be adequate from the heat-insulating point of view. However, syntactic rollers do not have the required wear resistance and frictional properties.

Another aim of the invention is, therefore, to provide a syntactic roller having improved wear resistance and frictional properties.

The present invention provides a method of coating a syntactic article, the method comprising the steps of positioning the article accurately within the cavity of a vacuum tool so that a predetermined gap exists between the article and the tool, and subjecting the cavity to a vacuum thereby drawing coating material into the cavity so as to coat the article, wherein the coating material has high wear resistance and good heat resistance properties, a high impact resistance and a predetermined coefficient of resistance.

According to the invention there is provided an article for use in forming thermoplastics material comprising a plug of syntactic material having a coating with good heat resistance.

According to another aspect of the invention there is provided a method of coating a syntactic article, the method comprising the steps of forming a plug comprising syntactic material and coating the plug with a material having good heat resistance.

According to a further aspect of the invention there is provided a method of forming thermoplastics material comprising the steps of a syntactic material having a coating of good heat resistance within a cavity of a tool so that a gap exists between a portion of a cavity wall and the article and drawing a thermoplastic material into the cavity to coat the article.

Advantageously the coating material is an elastomer. Urethane elastomers are suitable for use in the invention.

Preferred polymers are polyurethanes obtainable by reaction of a polyol with a diisocyanate. Preferably the polyol has an average molecular weight of about 1000 to about 2000 especially about 1200 to about 1300. The polyol ma• be a polymer of a hydroxyacid or lactone preferably a C_2 to C_{10}, more preferably a C_4 to C_8 hydroxyacid or lactone. Still more preferably the hydroxyacid or lactone is an α,ω-hydroxyacid or lactone such as caprolactone. Other polyols include polyesters and glycols such as PTMEG.

Akxo Chemie NTR 104 elastomer is suitable for use in the invention. Other coating materials which need not be elastomers may be used. The coating material should have good heat resistance, high wear resistance, high melting and decomposition point, and high impact resistance. Preferably the coating is resistant to temperatures of about 170^{0}C preferably 200^{0}C or greater for extended periods in air ie at least 1 hour preferably at least 2 hours especially at least 8 hours.

Preferably the diisocyanate is p-phenylene diisocyanate or 1,4-cyclohexane diisocyanate, the trans isomer being preferred.

The coating material may be used as a prepolymer which is curable by heat, catalyst, curative or a combination thereof. A typical catalyst is 1,4-diazabicyclo [2.2.2] octane (DABCO) which would typically be present at about 0.1 to 0.2 wt %. Typical curatives include 1,4-butanediol, 1,4-cyclohexane dimethanol, Dianol

(Trade Mark) and Nourycure (Trade Mark)B diamine. The curative can be present in amount ranging from about 5 to 15wt%; the skilled worker will be readily able to determine the optimum amount of curative needed.

Known syntactic plugs for vacuum forming are secured by one or more studs screwed or glued into the plug. Because the studs are of substantially constant diameter it is relatively easy for the stud to be pulled from the plug. In some embodiments of the invention the securing means are provided with a shoulder to prevent their removal from the plug.

In a preferred embodiment, the syntactic article is a plug for use in a plug-assist vacuum forming operation. In this case, the plug may be formed from two syntactic cylinders and a metal insert, the two syntactic cylinders being bonded together around the insert prior to the syntactic material being machined to the desired plug shape. Preferably, the metal insert is of two-part construction, one insert part having an end plate and an internally-threaded shank, the other insert part having an end plate and an externally-threaded shank, the threaded shanks being complementary. In this case, each of the syntactic cylinders has a respective cylindrical recess in one planar end face thereof, and one of the syntactic cylinders has an axial through bore, the cylindical recess being sized and shaped to receive the end plate of said one insert part when the two syntactic cylinders are in face-to-face contact, and the axial through bore being

size to receive the shank of said one insert part. Preferably, the end plate of said other insert part is provided with means for attachment to a vacuum forming machine.

In another preferred embodiment, the syntactic article is a cylindrical roller for use in feeding plastics sheets to a vacuum forming machine. Advantageously, the roller is formed by accurately machining a generally cylindrical syntactic blank, by accurately boring an axial hole therethrough, and by bonding a steel shaft within the axial hole.

The invention will now be described in greater detail, by way of example, with reference to the accompanying drawings, in which:-

Figure 1 is a plan view of a first syntactic cylinder to be used for making a plug for use in a plug-assist vacuum forming process;

Figure 2 is a side elevation of the first syntactic cylinder;

Figure 3 is a side elevation of the second syntactic cylinder to be used for making the plug;

Figure 4 is a plan view of the second syntactic cylinder;

Figure 5 is a plan view of a first part of a metallic connector for fixing the plug to a vacuum forming machine;

Figure 6 is a side elevation of the first part of the metallic connector;

Figure 7 is a side elevation of a second part of the metallic connector;

Figure 8 is a plan view of the second part of the metallic connector;

Figure 9 is a schematic elevation of apparatus for coating the plug; and

Figure 10 is a part-sectional elevation of apparatus for coating a syntactic roller.

Figure 11 is a cross sectional side view of a mould for production of a plug.

Referring to the drawings, Figures 1 and 2 show a first syntactic cylinder 1 which is formed with a cylindrical recess 1a in one planar end surface thereof. Figures 3 and 4 show a second syntactic cylinder 2 which is also formed with a cylindrical recess 2a in one planar end surface thereof. The cylinder 2 is also formed with an axial through bore 2b.

Figures 5 to 8 show the two parts of a metal insert which is used to fix the plug formed by the two syntactic cylinders 1 and 2 to a vacuum forming machine. Figures 5 and 6 show the first metallic part 3, which has an end plate 3a and a hollow internally-threaded shank 3b. Figures 7 and 8 show the second metallic part 4, which has an end plate 4a and an externally-threaded shank 4b. The shanks 3b and 4b have complementary threads, so that the two parts 3 and 4 can be screwed together, as shown in Figure 6 where the part 4 is shown in dotted lines.

In order to form the plug, the first metallic part 3

is positioned within the second syntactic cylinder 2, with its end plate 3a snugly fitted within the recess 2a. The end plate 3a has thickness which is equal to twice the depth of each of the recesses 1a and 2a, so that it is a snug fit within these recesses when the syntactic cylinders 1 and 2 are fitted together (see below). The second metallic part 4 is then screwed into the first metallic part 3 until the end plate 4a rests against the non-recessed planar end surface of the second syntactic cylinder 2. The two syntactic cylinders 1 and 2 are then bonded together around the degreased end plate 3a, with the end plate 3a constituting (with the recess 1a) means for accurately aligning the two syntactic cylinders.

As shown in Figure 5, the end plate 3a is provided with a plurality of generally semi-circular keys 3c in its peripheral edge. These keys 3c help to lock in the bonding agent used to fix the two syntactic cylinders 1 and 2 together. As shown in Figure 8, the end plate 4a is provided with a drilled and tapped hole 4c and a tapped grub screw hole 4d for use in fixing the finished plug to a vacuum forming machine.

After the two syntactic cylinders 1 and 2 have been bonded together, the resultant syntactic body is machined to shape, forming a plug body 5 (see Fig. 9) of the same shape as (but slightly smaller than) the plug to be formed. The plug body 5 is then positioned in a mould cavity 6 of a vacuum tool 7. The vacuum tool 7 has two complementary jig parts 7a and 7b which can be bolted

together around the plug body 5. A vacuum line 8 passes through the jig part 7a and leads to the mould cavity 6. Similarly, an elastomer feed line 9 leads to the cavity 6 via the jig party 7b. A dummy spacer 10 is provided to hold the plug body 5 centrally within the cavity 6. An O-ring 11 provides a seal between the two parts 7a and 7b.

Once the plug body 5 is correctly positoned in the cavity 6, and the parts 7a and 7b are fixed firmly together, the cavity space surrounding the plug body is evacuated via the vacuum line 8, and an elastomer is drawn in via the elastomer feed line 9. The elastomer used is AKZO Chemie NTR 104 grade elastomer. This elastomer has high wear-resistance properties, a high melting point, good heat resistance properties and a high impact resistance. It does, therefore, produce a coating 5a for the plug body 5 which has these desirable properties. The finished plug then has all the advantages of known syntactic plugs, but does not suffer from their disadvantages. Moreover, because of the size and nature of the metal insert 3, 4 (which is basically an in-depth plate within the syntactic plug body), operating forces are transmitted more evenly from the vacuum forming machine to the plug, so that there is a considerably reduced risk of the plug shattering during vacuum forming operations.

Figure 10 shows vacuum tool 21 for vacuum coating a syntactic roller 22. The syntactic roller 22 is a cylinder of syntactic material which has been accurately machined

to a cylindrical shape and accurately bored to receive a central shaft 23. The shaft 23 is bonded to the syntactic roller 22. As with the embodiment of Figure 9, the syntactic roller 22 is accurately positioned with in the vacuum tool 21 so that a uniform gap exists between the roller and the tool. Once the roller 22 is correctly positioned within the tool 21, the tool cavity is evacuated via a vacuum line 24, and an elastomer is drawn into the gap between the roller and the tool via an elastomer feed line 25. The elastomer used is AKZO Chemie NTR 104 grade elastomer. Once cured, the elastomer forms a coating for the roller 22 which has good heat resistance, is tough and has the required frictional properties to ensure that sheets of plastics material can be fed therealong to a modern high-speed vacuum forming machine, even when the temperature of such sheets is of the order of 170°C to 180°C.

It is not essential that the syntactic material be machined from the solid state. As may be seen from Figure 11 in a further embodiment of the invention uncured or incompletely cured syntactic material 26 is poured into a mould 27 preferably of aluminium, which may be coated with a release agent. A slight excess of syntactic material is used. One or more bushes 28 releasably engaged to tool top 29 for example by bolts 30 are forced into the syntactic material. As the tool top 29 moves towards the syntactic material 26 the gap between the tool and top is reduced. The enclosed material is compressed and some escapes

between a pinch off disc 31 preferably of nylon having a taper, α, of about 1^0. This process especially if preformed in a vacuum ensures that the plug is free of voids. The syntactic material generally will contain a curing agent. The rate of curing can be increased by controlled heating. When the syntactic material is solid it may be removed from the mould and coated. Because it is possible to cast the syntactic material in shape corresponding to that of the mould, the amount of machining required is reduced or even eliminated.

CLAIMS

1. An article for use in forming thermoplastics material comprising a plug of syntactic material having a cast cured coating of a polyurethane elastomer with good heat resistance.

2. An article as claimed in claim 1 wherein the syntactic material is coated with a polyurethane elastomer, obtainably by reaction of a polyol with p-phenylene diisocyanate or 1,4-cyclohexane diisocyanate.

3. An article as claimed in claim 1 or claim 2 wherein the article is a roller for feeding sheets of plastics material to a vacuum forming machine.

4. An article as claimed in claim 3 comprising a cylinder of syntactic material having an axial hole and a steel shaft bonded within the hole.

5. An article as claimed in claim 1 or claim 2 wherein the article is a plug for use in a plug assists vacuum forming operation.

6. An article as claimed in claim 5 wherein the plug comprises two pieces of syntactic material bonded together around an insert, the insert comprising a first part having an end plate for bonding to the syntactic material and a second part provided with means for attachment to a vacuum forming machine.

7. A method of forming an article for use in forming thermoplastics material comprising the steps of

i) forming a plug comprising syntactic material

ii) cast coating the plug with a coating of a polyurethane

elastomer with good heat resistance, and

iii) curing the coating

8. A method of forming thermoplastics material comprising the steps of

i) positioning an article comprising a syntactic material having a cast coating of a polyurethane elastomer good heat resistance within a cavity of a tool so that a gap exists between a portion of a cavity wall and the article, and

ii) drawing a thermoplastic material into the cavity to coat the article.

9. A method as claimed in claim 8 wherein the thermoplastic material is drawn into the cavity by a vacuum and comprising the additional step of

iii) removing the thermoplastic material from the article.

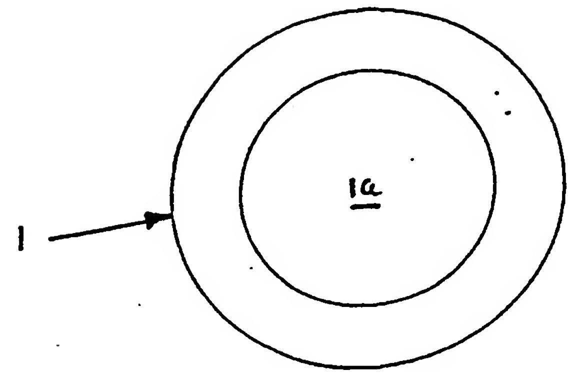

Fig. 1

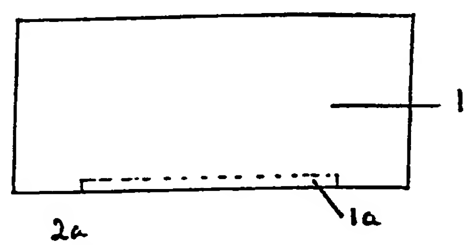

Fig. 2

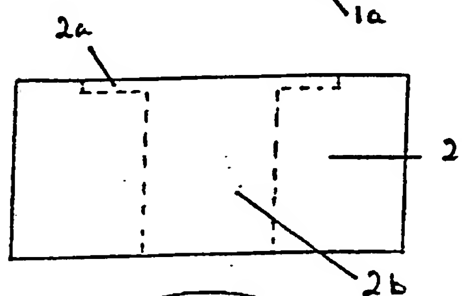

Fig. 3

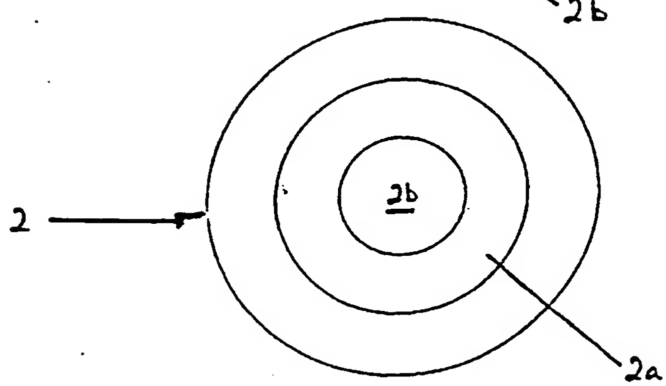

Fig. 4

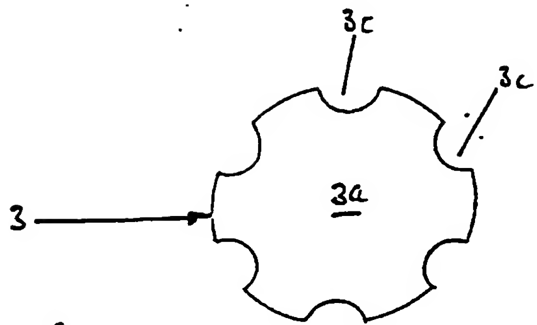

Fig. 5

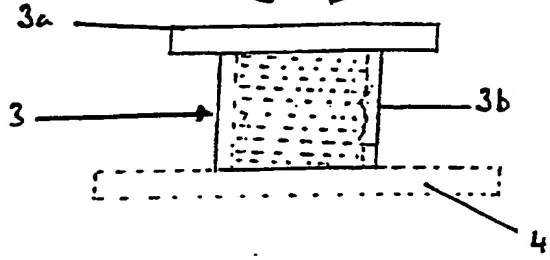

Fig. 6

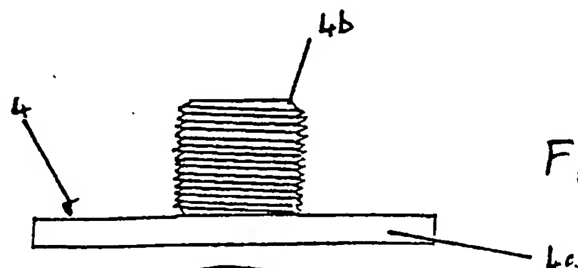

Fig. 7

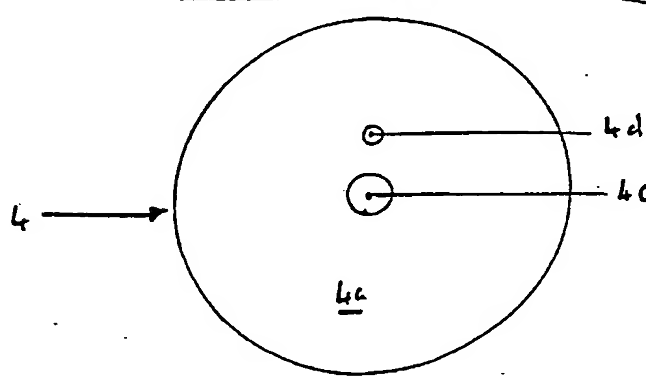

Fig. 8

3/5

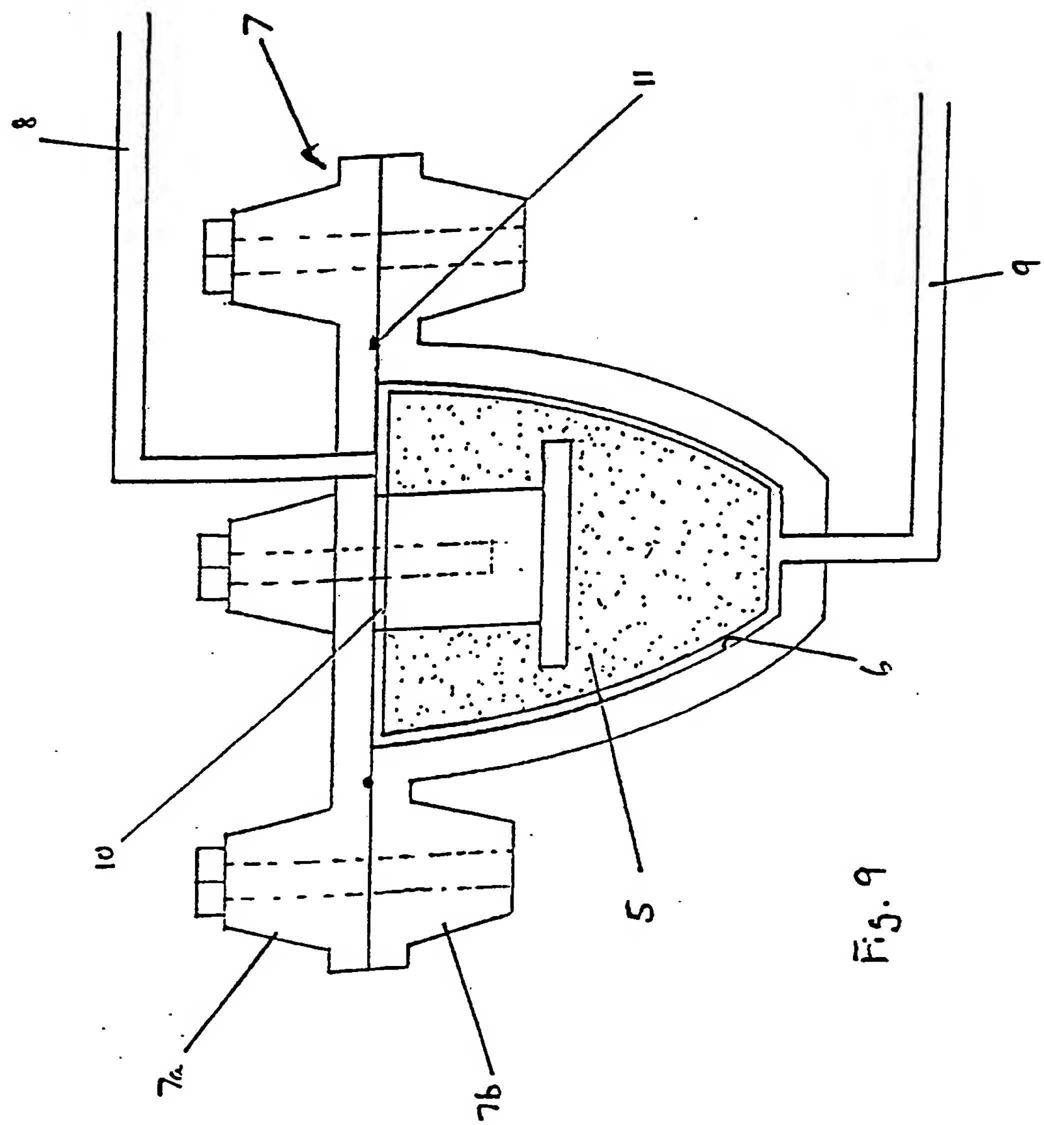

Fig. 9

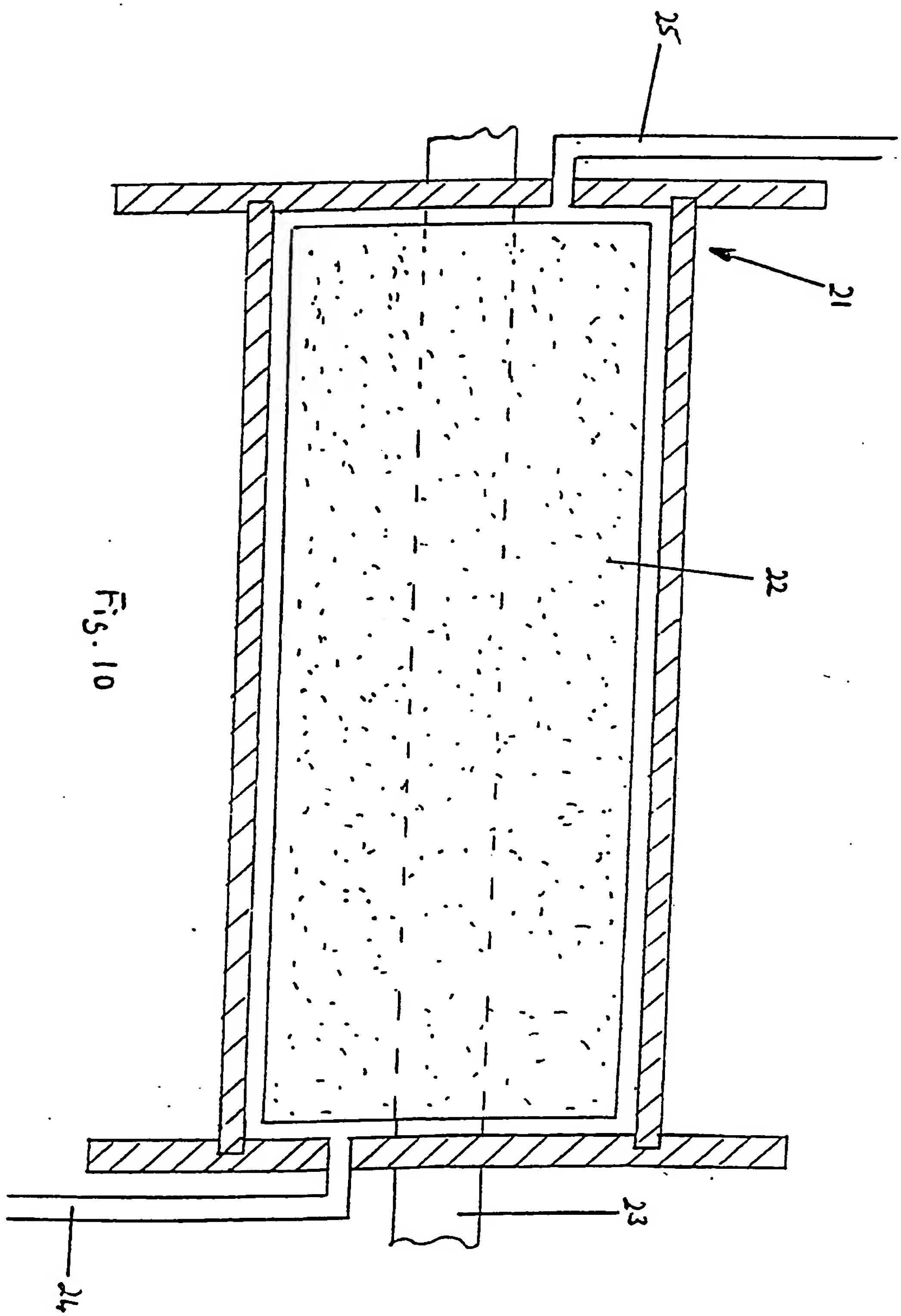

Fig. 10

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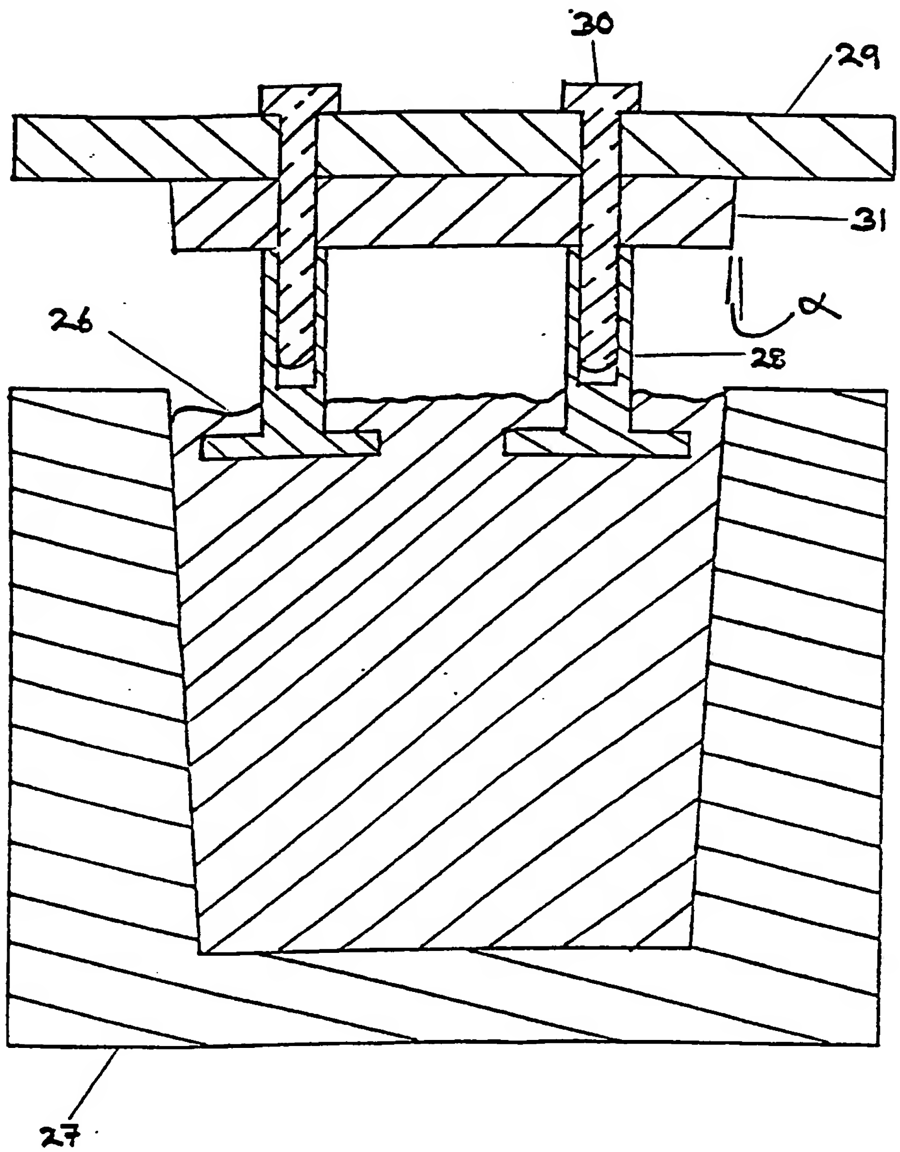

Figure 11

INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00529

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC^4: B 29 C 39/10; B 29 C 51/30; B 29 C 67/20

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC^4	B 29 C; C 08 J

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [*]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
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A	US, A, 3172159 (B. EDWARDS) 9 March 1965 see column 9, lines 61-64; claim 1; figures 15,20 --	1,5,6,8,9
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A	US, A, 3527854 (R. MARTIN) 8 September 1970 see abstract --	1,8,9
A	CH, A, 459557 (CHEMITEX) 13 September 1968 see column 1, line 27 - column 2, line 14 --	1
A	US, A, 4404258 (P. LOEWRIGKEIT) 13 September 1983 ./.	1

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
11th October 1988	28 OCT 1988
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

Form PCT/ISA/210 (second sheet) (January 1985)

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III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
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ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO.

GB 8800529
SA 23135

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report.
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